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THE OSTEOLOGY OF *KOTASAURUS YAMANPALLIENSIS*, A SAUROPOD DINOSAUR FROM THE EARLY JURASSIC KOTA FORMATION OF INDIA

P. YADAGIRI
Geological Survey of India, Bandlaguda, Hyderabad-500068, India

ABSTRACT—Extensive and well preserved sauropod material belonging to more than twelve individuals were recovered from the Early Jurassic Kota Formation of India. The sauropod *Kotasaurus yamanpalliensis* is characterized by simple dorsal vertebrae and a low iliac blade. Detailed osteological description of *Kotasaurus* is presented. The characters that distinguish *Kotasaurus* from the primitive sauropods are provided. It is considered to be one of the earliest sauropods and has some primitive features. The character analysis revealed that *Kotasaurus* is a basal sauropod in addition to *Vulcanodon, Shunosaurus, Barapasaurus,* and *Omeisaurus.*

INTRODUCTION

The evolutionary history of early sauropod dinosaurs was poorly known due to the lack of a good fossil record. In the past twenty years, there have been several studies of primitive sauropods (Raath, 1972; Jain et al., 1975; Wild, 1978; Dong et al., 1983; Cooper, 1984) but many problems regarding their origins and early evolution have not fully been resolved because of a dearth of material. The oldest known sauropod, *Vulcanodon,* was described by Raath (1972) from the Early Jurassic (Hettangian) beds of Zimbabwe but the skull and presacral vertebrae are unknown. The Lower Jurassic Kota Formation from India has yielded two dinosaurian taxa. *Barapasaurus tagorei* (Jain et al., 1975, 1979) has been classified as a sauropod on the basis of a number of sauropod features in its pelvic girdle, sacrum and vertebrae. In *Barapasaurus,* the skull and feet are unknown and the rest of the skeleton has received only a preliminary description. The second sauropod, *Kotasaurus yamanpalliensis* (Yadagiri, 1988), is characterized by simple dorsal vertebrae and a low iliac blade. The three taxa mentioned above, together with *Ohmdenosaurus* (Wild, 1978) and *Zizhangosaurus* (Dong et al., 1983) are tentatively assigned to the inadequately known family of Vulcanodontidae (McIntosh, 1990). Recently, Gauthier (1986), has placed *Barapasaurus* and *Vulcanodon* as close sistergroups of sauropoda. Bandyopadhyay and Roychowdhury (1996) opined that in view of incomplete knowledge about these two dinosaurs, it is not possible to either exclude or include them in the sauropod clade. Given this background, it is believed that the well preserved material of *Kotasaurus* will add new information on a relatively poor fossil record of early sauropods.

The Kota Formation in the Pranhita-Godavari valley (Fig. 1, Table 1) has yielded a huge collection of skeletal parts belonging to more than twelve individuals of *Kotasaurus* (Fig. 2). In view of the protracted nature of the study, a preliminary account of *Kotasaurus* was published (Yadagiri, 1988). Recently, the preparation work of skeletal parts and sorting of different elements were completed. The objective of this report is to present a more detailed description of the osteological characters of *Kotasaurus* with an emended diagnosis.

MATERIALS AND METHODS

During the search for vertebrate fossils in Upper Gondwana formations, surface finds of dinosaurian material were recorded near Yamanpalli village. The Yamanpalli excavation has exposed a large area measuring 2,400 m^3 and 840 dinosaur skeletal parts were recovered (Fig. 3). The clay horizon bearing the fossils overlies the cross-bedded sandstone, and is itself overlaid by thin bands of limestone intercalated with marls.

Of the excavated specimens, a few are complete and most of them partial. It became clear that the assemblage contains parts of at least twelve individuals based on the 23 specimens of femora that fall into five approximate size groups. The collection recovered from the Yamanpalli excavation includes: 31 cervicals; 65 dorsals; 192 caudals (99 proximal caudals and 93 distal caudals); 19 sacrals (one with three fused centra, two with two fused centra, sacral rib, sacricostal yoke and isolated sacral centra); three ilia; five fragmentary iliac plates; 14 pubic peduncles; seven ischiadic peduncles; four pubes (two restored, two proximal parts); 17 humerii (seven complete, three distal parts, seven proximal parts); 21 tibiae (six complete, eight distal parts, seven proximal parts); eight fibulae (six complete, two incomplete); and 23 femora (nine complete, 14 incomplete). All specimens are housed in the collection of the Geological Survey of India in Hyderabad. Recently, a composite skeleton of *Kotasaurus yamanpalliensis* was assembled by the author at the B. M. Birla Science Centre in Hyderabad, India.

Size variation can clearly be seen in all the skeletal parts (Tables 2–4). The largest femur measures 1,390 mm in length, whereas the smallest is 1,130 mm. The largest humerus measures 850 mm in length, whereas the smallest is 680 mm. However, the osteological characters of different individuals are similar, so they are considered to belong to a single species, *Kotasaurus yamanpalliensis.*

STRATIGRAPHY AND AGE

The Upper Gondwana of the Pranhita-Godavari Valley, Central India, was considered to consist of three formations, namely Maleri, Kota, and Chikiala in order of succession (King, 1881). Of these, the Maleri and Kota formations were grouped together earlier, and known as the Kota-Maleri beds (Hughes, 1876) until King separated them on faunal, lithological, and stratigraphical grounds. The Maleri Formation contained a Triassic fauna while the Kota Formation had a Liassic fauna. Later, Jain et al. (1964) and Kutty (1969) modified the stratigraphy in the light of additional vertebrate fossils collected from these formations. A revised stratigraphic succession of the Kota-Maleri sequence (Table 1, Fig. 1) is based on the work by Jain et al. (1964), Kutty (1969), and Yadagiri (1988).

The Kota Formation has yielded a rich vertebrate fauna of Semionotiformes (*Lepidotes deccanensis, Paradapedium egertoni,* and *Tetragonolepis oldhami*); Coelacanthiformes (*Indo-*

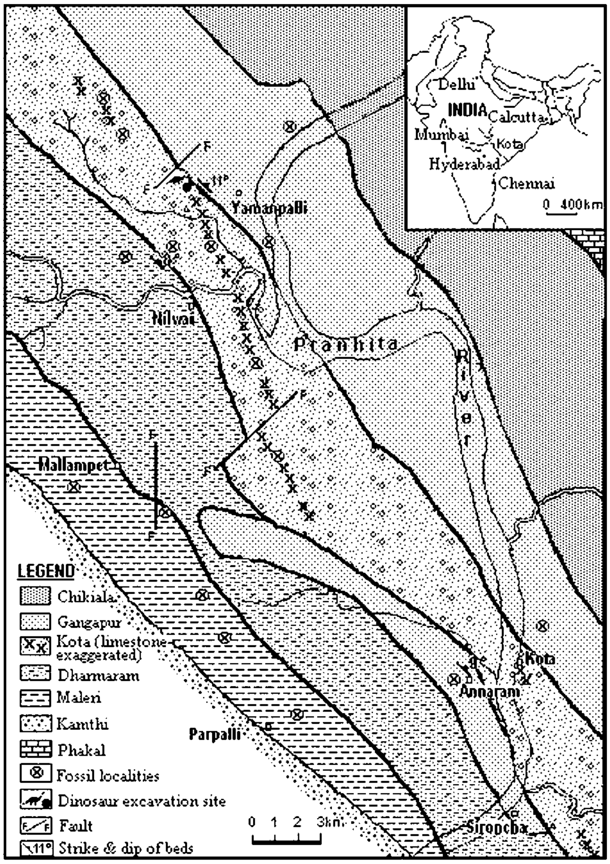

FIGURE 1. Geological map of the Yamanpalli area, Andhra Pradesh, India, showing the dinosaur excavation site.

coelacanthus robustus); Pterosauria (*Campylognathoides indicus*); Pholidophorids (*Pholidophorus kingii* and *P. indicus*); Sauropodomorpha (*Barapasaurus tagorei* and *Kotasaurus yamanpalliensis*); and Symmetrodonta (*Kotatherium haldanei*, *Trishulotherium kotaensis*, *Indotherium pranhitai*, and *Nakunodon paikasiensis*).

The Kota Formation consists of sandstones, clays and a prominent zone of limestone, which were deposited under fluviatile and lacustrine conditions.

The age of the Kota Formation has largely been based on the evidence of the actinopterygian fishes. The hypsisomid semionotids *Tetragonolepis* and *Paradapedium* (Jain, 1973) and *Pholidophorus* (Yadagiri and Prasad, 1977) suggest an Early Jurassic age for the Kota Formation. The Kota limestone has also yielded a flying reptile which has been referred by Jain (1974) to the genus *Campylognathoides* which is also known from the Upper Lias of Holzmaden, West Germany.

SYSTEMATIC PALEONTOLOGY

Order SAURISCHIA Seeley, 1888
Sub-order SAUROPODOMORPHA, Von Huene, 1932
Infraorder SAUROPODA Marsh, 1878
Family INCERTAE SEDIS
Genus *KOTASAURUS* Yadagiri, 1988

Holotype—Ilium (21/SR/PAL).

Referred Specimens—As mentioned by the registration number in the text and tables.

Emended Diagnosis—(Modified from Yadagiri, 1988). *Kotasaurus* differs from all known sauropods in a number of features: simple dorsal vertebral neural spines (without spinal laminae); a pneumatocoel on the base of the neural arch that opens into the neural canal is not present; low iliac blade; a narrow proximal surface to the scapula; relatively slender limb bones, the femur retaining the lesser trochanter; and 'v' shaped chevrons with well developed articular facets on the dorsolateral corners.

DESCRIPTION

Teeth—In the excavation, five dinosaurian teeth were found associated with the sauropod skeletal parts. Three teeth are of

TABLE 1. Lithological sequence in the Yamanpalli area (the Upper Gondwana formations of Pranhita-Godavari Valley).

Formation	Lithology	Thickness in mtrs.	Characteristic fossils	Age
Chikiala	Ferruginous sandstones with conglomerates.	400	Plant fossils	Early Cretaceous
Gangapur	Highly calcareous sandstones, fine grained sandstones with interbedded clays, basal part conglomeratic with pebbles of quartz, quartzite and chert, mudstones, etc.	500	Fossil wood, plant fossils, etc.	Early Cretaceous
	Red clays with interbedded siltstones and thin layers of ferruginous clay.			
Kota	Argillaceous, bedded limestones, beds locally laminated and with desiccation cracks.	100		Early Jurassic
	Red and green clays with interbedded sandstones.	30	Fishes, flying reptiles and bivalved crustaceans.	
*	Current bedded grey calcareous sandstones grading to conglomerate in places with pebbles of quartzite, quartz and chert.	50	Dinosaurs, early mammals.	
Dharmaram	Sandstones with interbedded red clays at places indurated mud stones.	500	Prosauropods	Late Triassic
Maleri	Red clays with interbedded sandstones and lime concretions.	300	Metoposaurs, Rhynchosaurs, Phytosaurs.	Late Triassic

*Yamanpalli dinosaur site.

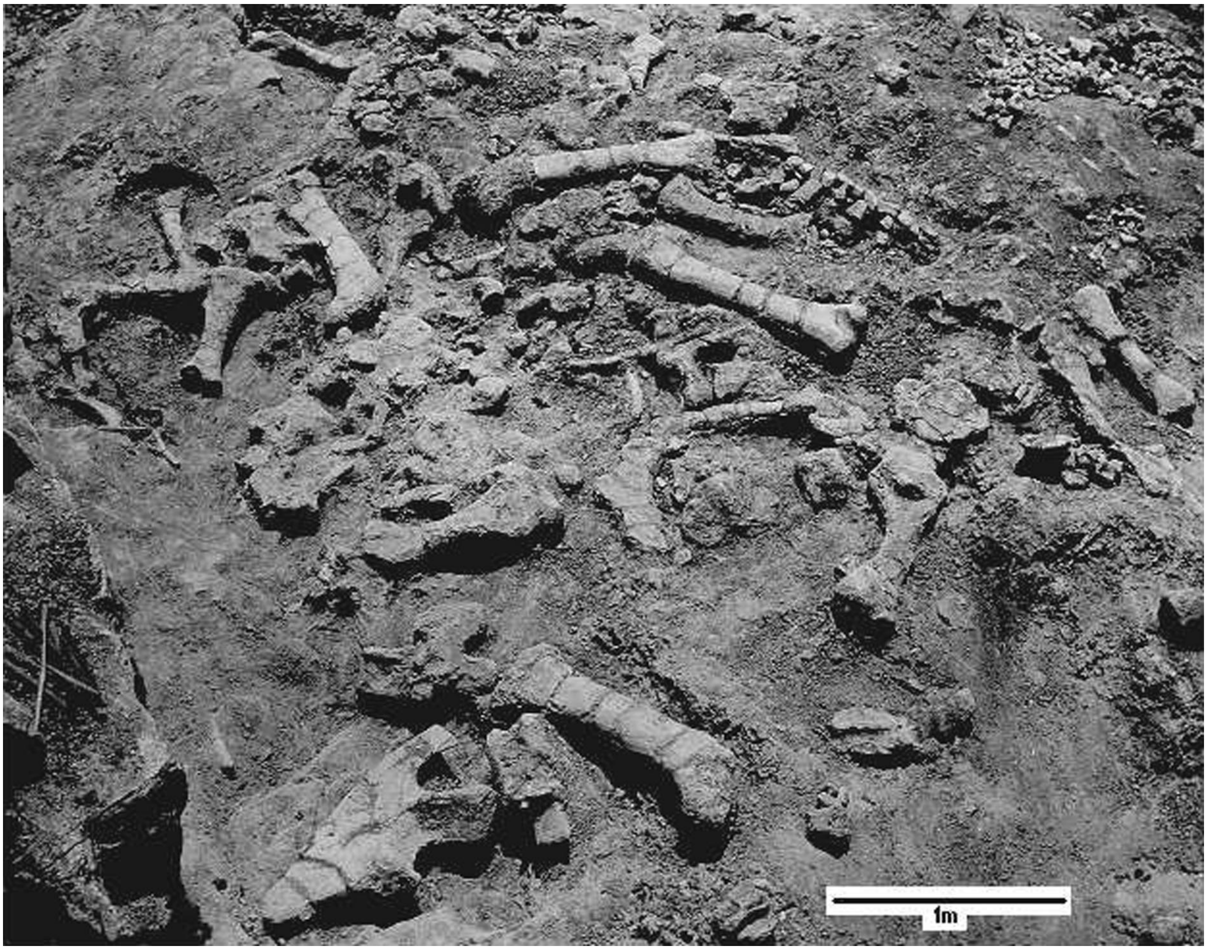

FIGURE 2. Distribution of the fossil bones of *Kotasaurus* in the Yamanpalli excavation site. Scale bar equals 1 m.

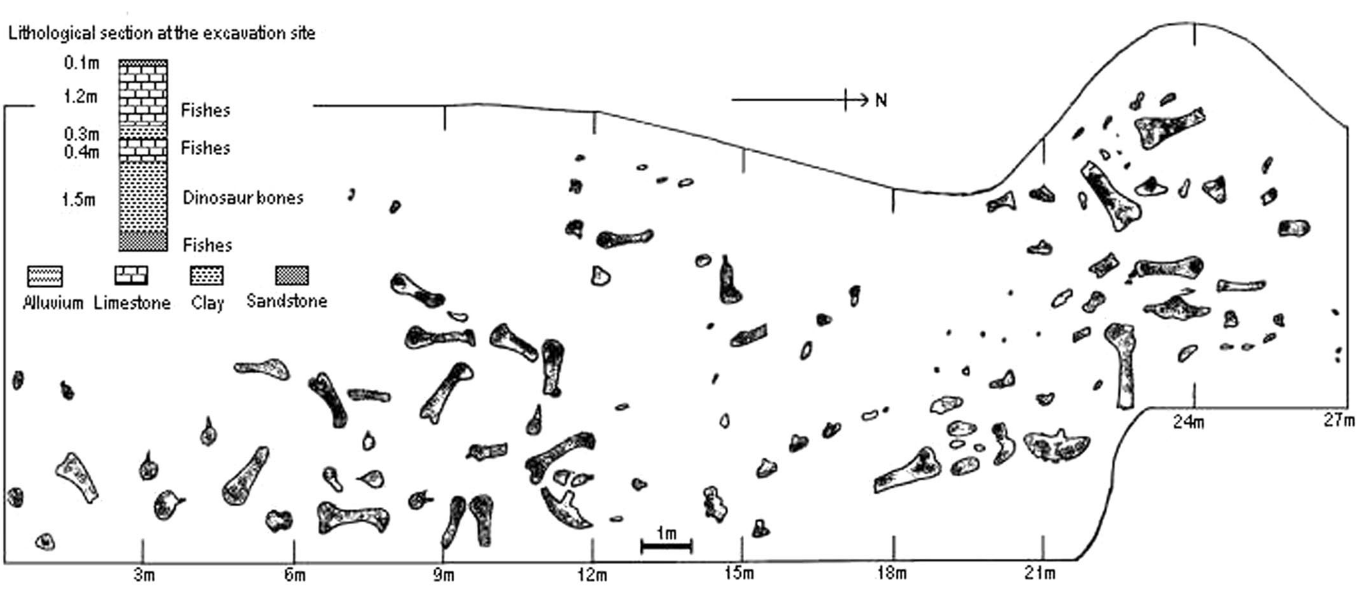

FIGURE 3. View of the fossil bones exposed in the excavation near Yamanpalli. Scale bar equals 1 m.

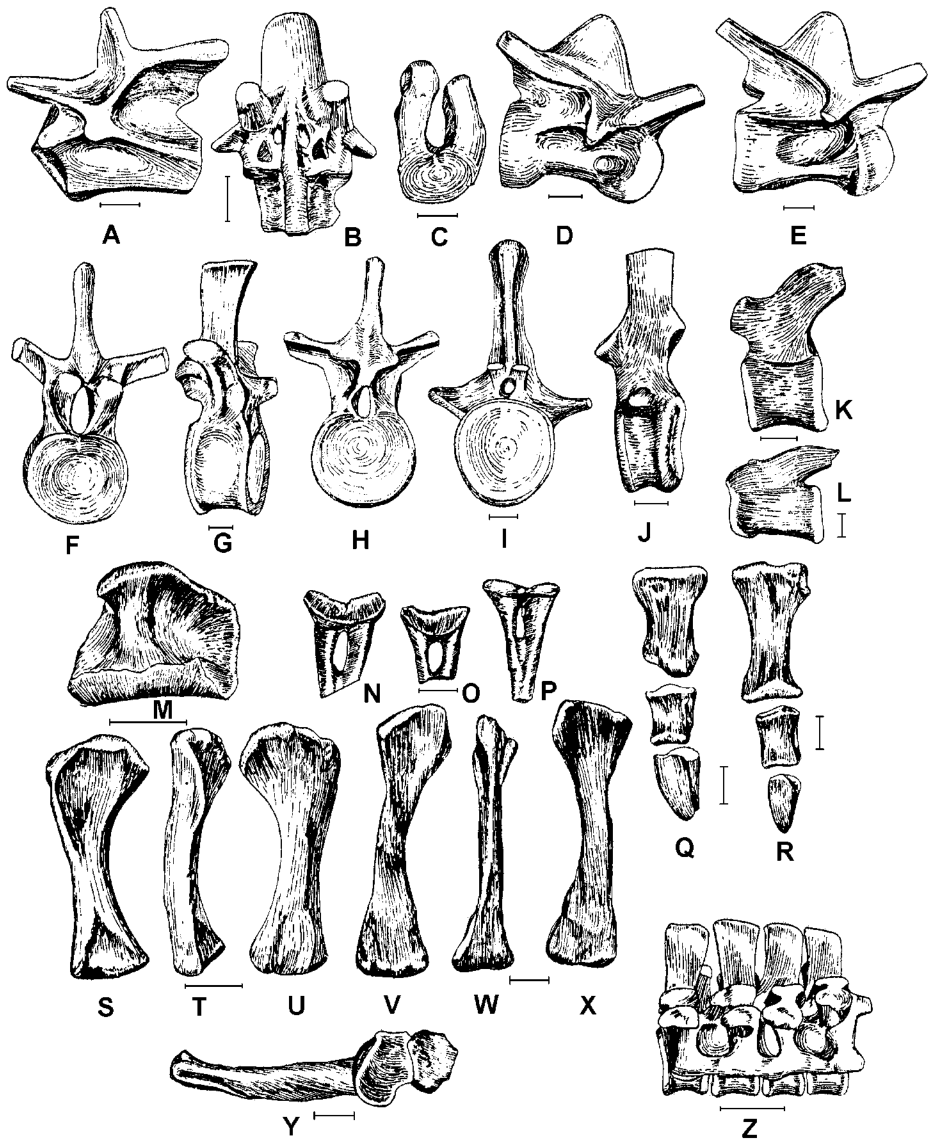

FIGURE 4. Skeletal elements of *Kotasaurus yamanpalliensis.* **A**, lateral view and **B**, anterior view of the axis; **C**, anterior view of the atlas; **D**, **E**, lateral view of cervical vertebrae; **F**, **G**, **H**, dorsal vertebra (anterior, lateral and posterior views); **I**, **J**, proximal caudal vertebrae (anterior and lateral views); **K**, **L**, posterior caudal vertebrae (lateral view); **M**, astragalus (anterior view); **N**–**P**, chevrons (anterior views); **Q**, **R**, digitals (anterior view); **S**–**U**, humerus (anterior, lateral and posterior views); **V**–**X**, ulna (lateral, anterior, posterior views); **Y**, scapulacoracoid (lateral); **Z**, sacrum (lateral view). Scale bar equals 20 cm (S–U; Y, Z); 10 cm (V–X); 5 cm in others.

carnosaur predators. Two teeth belong to Sauropoda. They are spoon-shaped with a smooth margin. The height of the crown is 15 mm and maximum width at the base is 10 mm. The apex is pointed. In the transverse view, the external surface of the tooth is convex and the apex is curved. On the internal side, the tooth is concave and bulges out near the base. Two grooves run from the base of the crown to the apex. The teeth are comparable to *Amygdalodon* in being short and having a curved apex (Fig. 7A, B).

Axial Skeleton

The vertebral formula of *Kotasaurus* is not known. Based on *Shunosaurus* and other sauropods, it is assumed to consist of 12 cervicals, 13 dorsals, 4 sacrals, and 43 caudals.

Cervical Vertebrae (Figs. 4A–E, 7E; 1 to 12/S1Y/76)—Twelve isolated cervical vertebrae including the atlas and the axis are well preserved, two of the cervicals being coalesced. The atlas is subrounded with a strong neural arch, and is constricted between the neural canal and the cavity for the odontoid process. The axis is nearly complete. The neural spine is short, wide, convex in the anterior and concave posteriorly. The odontoid process is wedge-like and projects outward from the centrum.

All cervical centra are strongly opisthocoelous. The anterior portion of the cervical centra has a strong, hemispherical convex articular surface, while the posterior surfaces are concave and considerably larger with pronounced rims.

The transverse processes are directed laterally and become wide from the mid-cervical vertebrae onwards. The well-developed diapophyses are small in the anteriormost cervical vertebrae but become somewhat larger and more robust from the mid cervicals backwards, projecting outward and a little upward. Pleurocoels are absent. The prezygapophyses are widely divergent, supported by supraprezygapophyseal laminae. The

TABLE 2. Measurements of cervical vertebrae of *Kotasaurus.*

Sp. No.	Length of centrum	Width	Height	Height of neural spines	Height of neural arch
IA/SIY/76	30	110	85	—	—
1/SIY/76	220	90	45	90	140
2/SIY/76	190	115	110	80	110
3/SIY/76	220	110	100	60	105
4/SIY/76	220	155	120	55	80
5/SIY/76	220	120	150	105	110
6/SIY/76	210	110	100	105	135
7/SIY/76	210	110	100	105	135
8/SIY/76	140	135	145	125	—
9/SIY/76	150	130	115	140	—
10/SIY/76	255	125	135	130	130
11/SIY/76	260	125	140	125	165
12/SIY/76	260	130	145	140	165

postzygapophyses are high and supported by infra-postzygapophyseal laminae. Intraprezygapophyseal and intrapostzygapophyseal laminae are present in all the cervicals. The neural canal is rounded and increases in size from anterior to posterior in the cervical series. The neural spines are single and not bifurcated, moderately high, and are slightly swollen at their tips. The shape of the neural spines is crescentic. The cervical ribs are not preserved. The parapophyses are consistently placed low on the anterior rim of the centra throughout the cervical region. Cervical measurements are given in Table 2.

Dorsal Vertebrae (Figs. 4F–H, 7G–I; 13 to 25/S1Y/76)—The anterior dorsals are opisthocoelous and the rest are platycoelous. The centra have lateral depressions, which may be either deep and small, or shallow and large. The measurements of the dorsal vertebrae are given in Table 3. The neural arches and the neural spines together make up nearly two-thirds of the total height in all the available dorsal vertebrae. The neural arches are wide in the anterior dorsals. The neural canal is large and rounded. The transverse processes are robust and directed laterally and upward. The articular facets on the transverse process are quite prominent. There is a gradual change in the position of the parapophyseal facets from the anterior to the mid dorsals. These are placed high on the anterolateral corner of the centrum in the three anterior dorsal vertebrae. However, the parapophyses move further upward on the neural arch and occur close to the diapophyses in the mid dorsal region. There are three laminae on the transverse processes. The centrodiapophyseal lamina extends from the diapophyses downward to the centrum. The postzygodiapophyseal lamina is directed backward to the postzygapophysis, and the prezygodiapophyseal lamina directed forward to the prezygapophysis. The laminae together form the strong and deep cavity on the neural arch. The prezygapophyses are placed closely whereas the postzygapophyses are placed quite wide apart. The postzygapophyses are cup-shaped. The undivided neural spine is of medium height and simple.

The dorsal centra are spindle-shaped; length, diameter of posterior face and height are nearly equal. The anterior and posterior faces of the centra are little concave. The neural arch is strong and is nearly equal to the height of the centrum. The hyposphene-hypantrum articulation is strongly developed.

Sacrum (Fig. 4Z; 26/S1Y/76)—The best available specimen among the collection of nineteen sacral specimens was selected for description. The full restoration of the sacrum was also based on features of the incomplete specimens.

The co-ossified sacrum consists of four centra, the centra being platycoelous. The total length of the sacrum is 590 mm, width is 530 mm, and height is 560 mm. The second and third neural spines are close, but not fused. The transverse processes are wide, thick and raised upward. The neural canal is rounded. The second sacral rib is complete, dorsally it has a wing-like robust expansion that arises from the neural arch. Distally, the rib is much expanded, which indicates its fusion. The sacricostal yoke probably is set close and does not contribute to the acetabulum. The neural spines are high.

Caudal Vertebrae (Figs. 4I–L, 7J, K; 29–81/S1Y/76)—All the caudal vertebrae are amphicoelous throughout the series. Both the height and the length of the caudals progressively decrease from the proximal to the distal caudals (Table 4). All caudals are constricted in the middle part of the centra. The distal caudal centra are even more constricted. Chevron facets occur on both anterior and posterior ventral margins of the centra. The chevron facets on the posterior ventral margin are placed on a raised ridge, but on the anterior ventral margin they are located on comparatively low ridge. Length and width of the anterior and posterior articular surfaces of the centra are more or less equal.

The neural arch is lower in the proximal caudals than in the dorsal vertebrae. The height of the arch decreases progressively from the mid caudals to the distal caudals. Hyposphene-hypantrum articulations are present up to the anterior caudals. Prezygapophyses are rod-like with spatulate articular facets and extend well beyond the anterior margin of the centra. The articular facets of the postzygapophyses are also spatulate but are smaller. The rounded neural canal is well marked in all the caudal vertebrae. The neural spine is simple and undivided. The neural spines of the proximal caudals are narrow and slightly

TABLE 3. Measurements of dorsal vertebrae of *Kotasaurus.*

Sp. No.	Length of centrum	Width	Height	Height of neural arch	Height of neural spine	Width	Length of trans. process
13/SIY/76	245	140	140	140	125	90	—
14/SIY/76	260	150	140	190	115	90	—
15/SIY/76	135	140	130	170	180	110	140
16/SIY/76	150	180	160	160	190	90	130
17/SIY/76	140	170	190	180	175	110	130
18/SIY/76	150	150	160	210	170	110	145
19/SIY/76	160	190	170	165	195	110	170
20/SIY/76	145	170	180	180	180	120	135
21/SIY/76	140	190	160	180	200	115	140
22/SIY/76	145	200	200	200	220	110	120
23/SIY/76	160	210	160	180	200	120	140
24/SIY/76	160	190	170	195	230	110	140
25/SIY/76	160	210	160	180	200	120	140

TABLE 4. Measurements of caudal vertebrae of *Kotasaurus.*

Sp. No. 1	Centrum length 2	Width 3	Height 4	Neural arch (height) 5	Neural spine (height) 6	Transverse process (length) 7	Total height 8
29/SIY/76	85	180	195	120	270	350	540
30/SIY/76	95	180	200	120	270	360	540
31/SIY/76	110	170	190	125	220	370	530
32/SIY/76	105	160	200	130	190	410	520
33/SIY/76	90	160	160	90	210	380	490
34/SIY/76	95	200	175	100	200	370	485
35/SIY/76	75	185	180	100	190	340	460
36/SIY/76	110	180	180	120	190	370	480
37/SIY/76	90	180	160	90	160	370	460
38/SIY/76	90	170	170	90	160	370	470
39/SIY/76	105	160	180	90	150	360	440
40/SIY/76	120	170	160	80	150	360	—
41/SIY/76	95	160	150	80	150	350	450
42/SIY/76	95	160	170	70	260	320	430
43/SIY/76	100	150	170	70	160	310	430
44/SIY/76	100	150	170	65	150	320	410
45/SIY/76	100	145	170	65	150	320	450
46/SIY/76	90	145	160	65	150	320	430
47/SIY/76	100	160	160	70	140	300	400
48/SIY/76	95	170	170	100	140	310	420
49/SIY/76	110	130	145	80	150	280	380
50/SIY/76	100	150	140	70	150	300	390
51/SIY/76	90	130	140	60	120	300	360
52/SIY/76	95	125	140	70	130	320	400
53/SIY/76	85	120	150	70	140	270	390
54/SIY/76	100	120	130	50	120	260	370
55/SIY/76	100	120	130	50	125	270	360
56/SIY/76	105	110	120	50	120	260	350
57/SIY/76	85	90	140	50	140	270	360
58/SIY/76	90	110	130	50	120	260	330
59/SIY/76	100	105	125	60	100	270	310
60/SIY/76	90	110	120	70	120	260	310
61/SIY/76	105	95	110	50	120	220	260
62/SIY/76	95	110	110	50	110	240	280
63/SIY/76	90	90	100	40	110	220	220
64/SIY/76	105	110	120	80	120	220	310
65/SIY/76	130	135	130	40	80	220	300
66/SIY/76	100	110	130	40	80	—	290
67/SIY/76	100	110	130	40	80	—	290
68/SIY/76	130	80	90	—	—	—	140
69/SIY/76	110	80	90	—	—	—	140
70/SIY/76	110	80	90	—	—	—	140
71/SIY/76	100	80	85	—	—	—	130
72/SIY/76	100	80	85	—	—	—	125
73/SIY/76	100	80	85	—	—	—	120
74/SIY/76	100	80	85	—	—	—	120
75/SIY/76	100	80	85	—	—	—	120
76 to 81	90	45	45	—	—	—	—

swollen at their tips, these are almost perpendicular to the neural canal. The mid caudal spines appear to be laterally compressed. The neural spines of distal caudals are strongly oriented backward. The transverse processes emerge from the junction of the centrum and neural arch in the proximal and mid caudals.

Chevrons (Figs. 4N–P, 8R; 82–89/S1Y/76)—Ten chevrons were collected of which five are well preserved. The size range of the chevrons indicates that these belong to anterior and midcaudals. The chevron specimens measure 70, 55, 50, and 45 mm in length. Viewed from the front or back chevrons are nearly straight. The chevrons may be described as a bridged over V or triangular, with well developed articular facets on the dorsolateral corners. From the ventral apex of the chevron, a stout spine projects ventrally and then curves slightly posteriorly. The hemal canal below the head is quite large. The hemal spine is transversely compressed.

Pectoral Girdle

The pectoral girdle is represented by a scapula and a coracoid, both from the right side. These were not fused.

Scapula (Figs. 4Y, 7D)—The scapula (100/S1Y/76) is a long, slender bone, measuring 1,230 mm in length. It shows a slight longitudinal curvature. The external surface of the scapular blade is moderately convex, while the internal surface is concave. It is broadly expanded both proximally and distally, the breadth being about one-fourth of the total length of the bone. The distal end of the scapula is rugose and it is bordered by a curved ridge. The width of proximal end measures 360 mm and the distal end 220 mm.

Coracoid (Fig. 7F)—The coracoid (101/S1Y/76) is well preserved and complete. It is subrectangular in outline and measures 340 mm in length. The anteromedial border is almost straight and thickened, while the remaining part is almost oval.

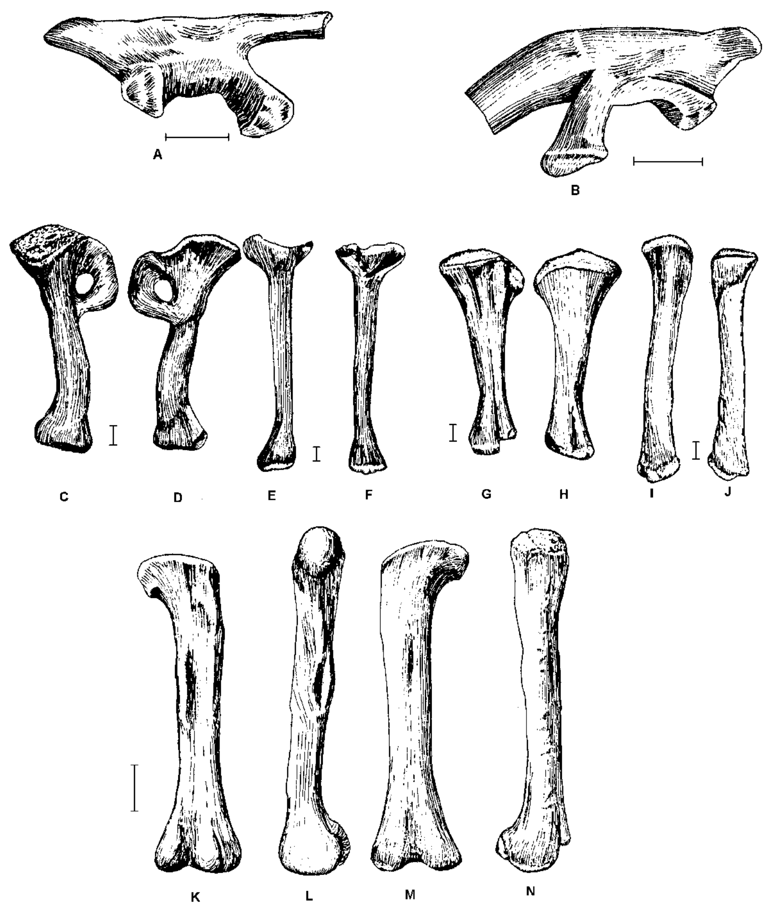

FIGURE 5. Pelvic and hindllimb elements of *Kotasaurus yamanpalliensis.* **A**, **B**, ilium (lateral and medial views); **C**, **D**, pubis (medial and lateral views); **E**, **F**, ischium (anterior and posterior views); **G**, **H**, tibia (posterior and anterior views); **I**, **J**, fibula (medial and lateral views); **K**–**N**, femur (posterior, medial, lateral and anterior views. Scale bar equals 20 cm (A, B, K–N); 10 cm in others.

It is irregularly convex on the lateral surface, concave on the inner surface. A prominent foramen is present.

Forelimb

The forelimb is represented by a well preserved humerus (102/S1Y/76), radius (106/S1Y/76), and ulna (107/S1Y/76). Carpals or phalanges have not been found.

Humerus (Figs. 4S–U, 8A–F; 102/S1Y/76)—The humerus has a constricted shaft with expanded ends. The proximal end is more expanded than the distal. A strong deltopectoral crest occupies the upper half of the lateral margin of its anterior face. The shaft of the humerus is twisted. The humerus measures 770 mm in length, proximal end 300 mm and distal end 240 mm.

Radius (106/S1Y/7)—The radius is a long and thin bone with an oval proximal articular surface. It measures 700 mm in length; the proximal end is 130 mm wide and the distal 140 mm wide. A shallow groove extends from about mid-length to the distal head. The distal end is strongly compressed transversely. The anterior edge of the extreme distal end is turned outwards to form a weak laterally directed crest.

Ulna (Fig. 4V–X; 107/S1Y/76)—The ulna is a robust bone stouter than the radius and v-shaped proximally. It has a transversely compressed cross-section at the midshaft. The proximal end is expanded posteriorly with a thin flange of bone. At midlength, the bone is reduced in width. The total length of the ulna is 710 mm, the width at midshaft is 90 mm. The proximal expansion is 210 mm and distal 185 mm. Two prominent projections are present, one at a short distance from the distal end, another on the medial surface at about midlength, probably for muscle attachments. The ulna shows a significant distal expansion, as well as curving away slightly from the radius.

Pelvic Girdle

The preserved pelvic elements include the complete right ilium (108/S1Y/76), left pubis (110/S1Y/76), and right ischium (109/S1Y/76).

Ilium (Figs. 5A, B, 7L, M; 108/S1Y/76)—The ilium has a characteristic low iliac blade. The dorsal border is almost straight. The bone flares laterally behind the acetabular region forming a shallow basin. The posterior process is at a slightly lower level than the ischiac peduncle, whereas the anterior process rises above the level of pubic peduncle and gradually runs upward. The pubic peduncle is long. The acetabular surface of the pubic peduncle is smoothly concave and the distal articular surface subtrigonal in outline. There is a distinct rim to the lateral acetabular surface of the ischiac peduncle. The ischiac peduncle is reduced and has a subtrigonal articular surface. The acetabulum is of moderate size by comparison to other sauropods.

Pubis (Figs. 5C, D, 7N, O; 110/S1Y/76)—The left pubis is incomplete with the iliac symphyseal region and shaft preserved. The pubis is stoutly built with a proximal expansion. The pubic foramen appears to open downward immediately below the acetabulum. The iliac peduncle is broad and subovate in shape.

Ischium (Figs. 5E, F, 7P, Q; 109/S1Y/76)—The right ischium is represented by the proximal portion and part of the shaft. The proximal end has a broadly expanded articulating surface for the peduncle of the ilium followed by a curved embayment marking the acetabular part of the ischium. Anteriorly it has thin facet for articulation with the pubis.

Hind Limb

The right and left limb elements are complete except for a broken mt.III.

Femur (Figs. 5K–N, 7G–L)—The femur (111/S1Y/76) is a relatively narrow, columnar bone measuring 1,130 mm in length. In anterior view, it is straight, lacking the sigmoid curvature seen in prosauropods, and with acuminate fourth trochanter placed at about midlength. The head of the femur is robust and takes a sharp incurve from the shaft without any constriction or neck. The shaft of the femur is wider (160 mm) than the anteroposterior thickness (80 mm). The lesser trochanter is preserved as a weak posterolateral ridge terminating about 160 mm below the femoral head. The distal end of femur has two well-developed condyles, the internal condyle being larger. The distal end measures 200 mm in anteroposterior thickness.

Tibia (Figs. 5G, H, 8M, P, Q)—The tibia (115/S1Y/76) is a large, laterally compressed bone with a large proximal end. The distal shaft is twisted relative to the long axis of the proximal side. The cnemial crest extends as a thick ridge, clearly demarcated from the lateral crest with a break in slope, going at a low level. A prominent shallow longitudinal groove is present on the surface of the midshaft of the tibia. The cnemial crest is well developed, protruding forward and curving slightly laterally. The proximal surface is higher in the middle and then slopes laterally. At the distal end, the width increases with a characteristic notch for articulation with the astragalus. The tibia is estimated to be about 64% of the femoral length. Tibia measures 730 mm in length, 370 mm at proximal and 230 mm at distal end.

Fibula (Figs. 5I, J, 8N, O)—The fibula (113/S1Y/76) is a slender bone with proximal and distal ends equally expanded. The proximal head is laterally compressed. The dorsal profile is crescentic, due to the strongly inturned anteromedial crest which bears a depression on its anterior surface. The medial surface of the proximal head is marked by a large, subtrigonal area for attachment with the tibia. The distal head is transversely compressed, thickest posteriorly, with the medial surface weakly excavated for articulation with the lateral surface of the astragalus.

Astragalus (Fig. 4M)—The left astragalus (116/S1Y/76) is a heavy bone, longest transversely (170 mm) and broadest laterally (100 mm), with a subtrigonal anterior profile. The ventral surface is trochlear roller-shaped, with a very irregular and pitted surface. Anteriorly, the ascending process rises towards the lateral side as a thick ridge with a slanting upper surface. On the posterior side, there is another upstanding ridge, lower in height than the dorsal ascending process. The two ridges are connected by a low saddle that has two concave surfaces, one small, lateral in position; the other large medially placed. The astragalus, in posterior view, shows a prominent boss in the dorsolateral corner which is homologous to the posterior overhang of the dorsal ascending process in the prosauropod condition (Cooper, 1980). A prominent astragalar peg is situated antroventrally, similar to the ankle of prosauropod.

Metatarsals (Fig. 4Q, R)—The metatarsals were found disarticulated. Metatarsals I, II, IV and V are complete but Mt III was broken at the proximal end. They are short and robust.

Metatarsal I is a strongly twisted bone. The shaft of the bone at midlength is trigonal in cross section and thickest medially. The distal end has two asymmetrical condyles with an oblique anterior groove. The other metatarsals have weak shaft with asymmetric condyles.

Phalanges—The phalangeal elements were found isolated. Phalanx I of the first digit is a prominent asymmetric bone with a pronounced expansion of the proximal head. The proximal articular surface shows a faint vertical division. In the distal part asymmetrical condyles are with deep grooves on lateral and medial surfaces. In dorsal view, the surface gradually slopes down from the proximal margin. The proximal articular surface is oval in outline with a depression in the center, and the dorsal and ventral margins projecting out.

The ungual phalanx (Fig. 8R–T) of digit I is a large, laterally compressed bone, with an asymmetrically biconcave proximal articular surface with a prominent vertical ridge. On ventral surface is a well developed flexor tubercle. The flattened lateral surface is marked by vascular groove on either side, extending from the region of the flexor tubercle almost to the tip of the claw. The tip of the specimen is broken however, it can be assumed to have been bluntly rounded. The phalanges in the collection are assigned to other digits based on the osteological characters.

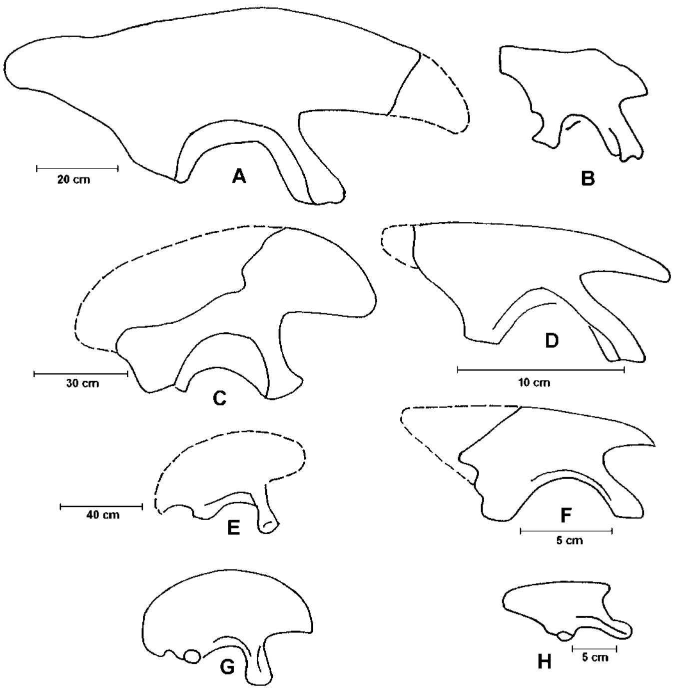

FIGURE 6. Comparison of ilia of *Kotasaurus* with other Sauropodomorpha (lateral view of right side). **A**, *Kotasaurus*. **B**, *Plateosaurus*. **C**, *Barapasaurus*. **D**, *Ammosaurus*. **E**, *Vulcanodon*. **F**, *Anchisaurus*. **G**, *Apatosaurus*. **H**, *Efraasia*. (After Galton, 1976; Raath, 1972; Jain and Chatterjee, 1979; and Yadagiri, 1988.)

DISCUSSION

The Kota Formation of the Pranhita-Godavari Valley, has yielded two sauropod dinosaurs so far. Jain et al. (1975) reported *Barapasaurus tagorei* from a locality near Pochampalli in Maharashtra state, and the material of *Kotasaurus yamanpalliensis* has been recovered from a locality 40 km north of the type locality of *Barapasaurus* (Yadagiri, 1988). *Kotasaurus* is known from extensive and well preserved material and although no complete articulated skeleton is known, a number of partially associated skeletal elements are present which allow a

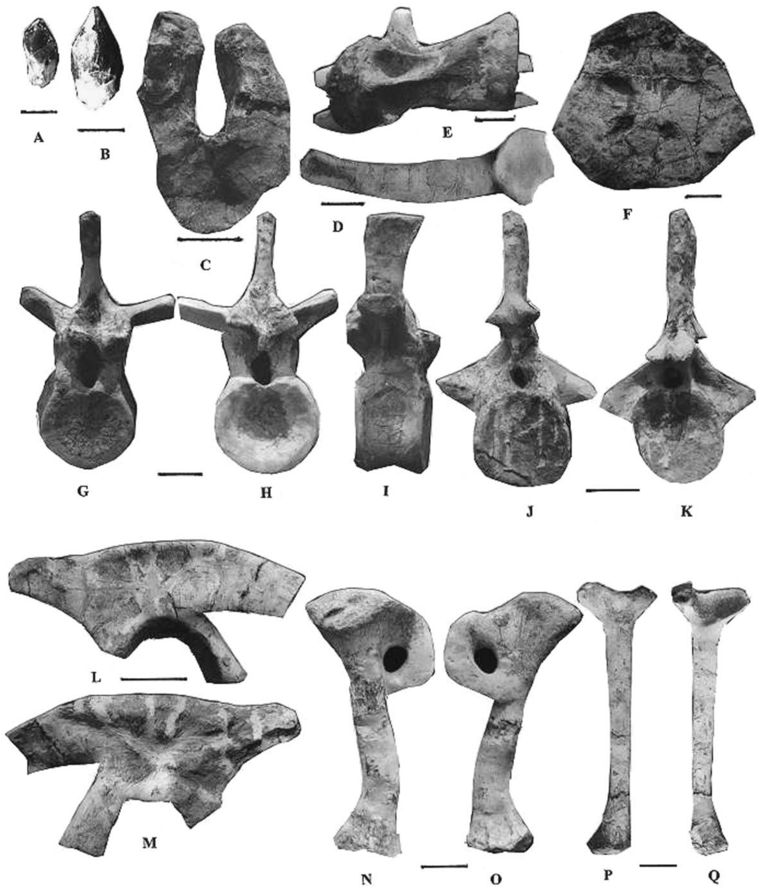

FIGURE 7. Skeletal elements of *Kotasaurus yamanpalliensis.* Isolated tooth in lingual (**A**) and labial (**B**) views; atlas in anterior view (**C**); scapula in lateral view (**D**); cervical vertebra in ventral view (**E**); coracoid in lateral view (**F**); dorsal vertebra in anterior, posterior and lateral views (**G–I**); caudal vertebra in posterior and anterior views (**J**, **K**); ilium in lateral and medial views (**L**, **M**); pubis in lateral and medial views (**N**, **O**); ischium in lateral and medial views (**P**, **Q**). Scale bar equals 20 cm (D, L, M), 10 cm (G–K, N–Q), 5 cm (C, E, F), 1 cm (A, B).

reasonably good restoration of the post-cranial skeleton. The scapula, caracoid, ilium and dorsal vertebrae were found in close proximity (Fig. 2) and were considered to belong to one individual. Recently, a partially articulated sauropod skeleton possessing the right hind limb elements was excavated from the Kota Formation near Kistapur (19°13′30″N; 79°31′E) in the Pranhita-Godavari Valley. The sizes of the femur and tibia are same as that of the *Kotasaurus* described above. The age of *Kotasaurus* is Early Jurassic in view of the occurrence of a definite Liassic fish fauna in limestone immediately overlying the sauropod-bearing horizon.

Kotasaurus has many of the sauropod synapomorphies established by Wilson and Sereno (1998:65; characters 1–12). The sauropod characters of *Kotasaurus* are well observed in the sacrum with four co-ossified vertebrae; the ilium in having an abbreviated ischiadic peduncle and extensive anterior process (Fig. 6, comparison of the ilia of sauropods and prosauropods); the pubis lacking the transverse 'apron'; the ischium with symphyseal contact restricted to a posterior portion; the femur with a straight slender shaft with elliptical cross-section, long axis of ellipse oriented medio-laterally and the fourth trochanter has an acuminate and slightly declined tip; the shape of the distal end of the tibia for its reception of the astragalus; and in many features of the cervical and dorsal vertebrae.

However, certain characters in other elements of *Kotasaurus* indicate a prosauropod condition. The humerus is less expanded both proximally and distally, with a slight twist of both the ends and lacking anteroposterior expansion in the dorsal end. The femur has retained a lesser trochanter, a symplesiomorphy shared with its prosauropod ancestor. The astragalus, having an astragalar peg and a prominent boss in the dorsolateral corner, indicates the prosauropod condition.

Kotasaurus has thus been classified as a sauropod on the basis of a number of sauropod features in its pelvic girdle, sacrum tarsals and vertebrae. It is considered as one of the earliest sauropods. Although *Kotasaurus* has several ''prosauropod-like'' features (see the review by Charig et al., 1965; Galton, 1976), these would have to be considered as primitive features. It can be differentiated from other sauropods in these characters: simple dorsal vertebrae; low iliac blade; the scapula with narrow proximal surface; and relatively slender limb bones.

The autapomorphies of *Kotasaurus* are: a low iliac blade and simple dorsal vertebrae. *Kotasaurus* is recognized as a new species, based on many skeletal differences with the early sauropods. *Kotasaurus* can be differentiated from *Barapasaurus*, which is also reported from the Kota Formation, in the following characters: simple dorsal vertebrae and lacking elaborated laminae on the neural spines as in *Barapasaurus*; a low iliac blade; and the femur retaining the lesser trochanter. Jain et al. (1979) mentioned that a modification in the neural canal region of posterior mid-dorsals is probably unique to *Barapasaurus tagorei*. The neural canal as mentioned by them becomes rather narrow, deeply sunk on the centrum ventrally, and opening dorsally into a large cavity through a narrow slit-like opening. But, in *Kotasaurus*, the neural canal is normal, in the sense that it is essentially a tubular feature running for nearly the whole

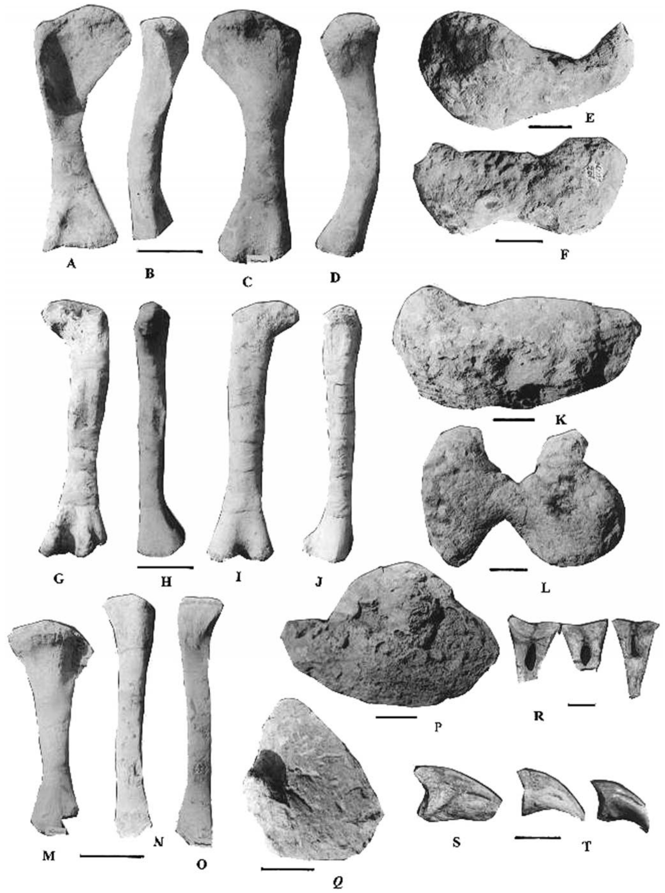

FIGURE 8. Skeletal elements of *Kotasaurus yamanpalliensis.* Humerus in anterior, lateral, posterior, medial, proximal and distal views (**A**–**F**); femur in posterior, medial, anterior, lateral, proximal and distal views (**G**–**L**); tibia in lateral, proximal and distal views (**M**, **P**, **Q**); tibia in lateral and medial views (**N**, **O**); chevrons in posterior view (**R**); ungual phalanx of digit II (**S**) and digit III (**T**). Scale bar equals 20 cm (A–D, G–J), 10 cm (M–O), and in others 5 cm.

length of the arch. The absence of a pneumatocoel on the base of the neural arch that opens into the neural canal in *Kotasauras* is a strong evidence to distinguish it from *Barapasaurus tagorei.* The transverse processes of dorsal vertebrae in *Kotasaurus* are directed upward, rather than horizontally as in *Barapasaurus* (Bandyopadhyay and Roychowdhury, 1996). These differences in the dorsal vertebrae of *Kotasaurus* and *Barapasaurus* clearly show that they are quite distinct from each other. *Barapasaurus* is often compared with *Vulcanodon* from Zimbabwe, which has been found near the Triassic–Jurassic boundary and is considered to be Hettangian in age by several authors (Raath, 1972; Cooper, 1984; Bonaparte, 1986). Bandyopadhyay and RoyChowdhury (1996) opined that *Kotasaurus* seems to be more similar to *Vulcanodon.*

Kotasaurus can be differentiated from *Vulcanodon* basically on the differences of pubis, ischium, sacrum, caudal vertebrae and chevrons. The pubis of *Kotasaurus* is expanded proximally like that of *Barapasaurus* and the ischium is narrow proximally. The sacrum in *Kotasaurus* possesses a sacricostal yoke, which is set closely and does not contribute to the acetabulum, whereas in *Vulcanodon* the sacricostal yoke is absent. The scapula in *Kotasaurus* is slender with narrow proximal expansion. Another difference can be seen in the size of caudal vertebrae. The caudal centra are longer than their heights in *Vulcanodon,* but are shorter than the centrum height in *Kotasaurus.* The chevrons of *Vulcanodon* (Cooper, 1984) are transversely compressed with dorsal surface closed. The chevrons of *Kotasaurus* are different from those of *Vulcanodon* having a bridged over triangular surface with well-developed articular facets on the dorsolateral corners.

Recent discussions and analyses of sauropod phylogeny have been reviewed by Wilson and Sereno (1998). Gauthier (1986) regarded *Vulcanodon* and *Barapasaurus* as the most primitive sauropods and listed 27 synapomorphies uniting them with other sauropods. Bonaparte (1986) recognized the advanced features of the presacral vertebrae of sauropods that are absent in the basal sauropods *Vulcanodon, Barapasaurus,* and several ''cetiosaurids.'' McIntosh (1990) presented phylogenetic trees that include additional phylogenetic structures. *Vulcanodon,* the earliest known sauropod, is positioned at the base of the tree as the ancestor to subsequent sauropods. Upchurch (1995, 1997) considered *Barapasaurus* and *Vulcanodon* to be successively more distant outgroups to the rest of the sauropoda (1995), or forming an unresolved trichotomy with the rest of sauropods (Upchurch, 1997). Based on 109 characters for ten sauropod taxa (Wilson and Sereno, 1998), the most parsimonous arrangement places four genera (*Vulcanodon, Shunosaurus, Barapasaurus,* and *Omeisaurus*) as a sequence of sister-taxa to a group of advanced sauropods. The character analysis of *Kotasaurus* has revealed that in addition to the four genera mentioned above, *Kotasaurus* is also a basal and primitive taxon of sauropods. The future work with discovery of improved cranial material of *Kotasaurus, Barapasaurus,* and *Vulcanodon* may prove that all these Hettangian to Lower Jurassic taxa belong to the Sauropoda.

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